RIGID VACUUM TIP

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of Parnell et al, US Serial No. 09/925,403, filed August 9, 2001, titled, "In-lay Station with Alignment Assemblies and Transfer Tubes", incorporated herein by reference.

1. Field of the Invention

The invention relates to a transfer tip useful in handling injection molded ophthalmic lens molds, and to a system and a process employing said transfer tip. The invention is particularly suited for use with high speed, vacuum and air pressure assisted robots that remove still-hot (hence deformable) soft contact lens mold halves from their injection molds, and transfer them to a production line pallet conveyor system for further processing. The transfer tip has a body portion of a substantially rigid material. In one embodiment, the transfer tip of the invention has a working end that has an outer surface that is complementary to the shape of the lens mold half being handled, this being either a convex or concave shape. In practice, this embodiment of the invention requires less applied vacuum and evacuation volume, for example, to achieve part pick up and transfer than designs known heretofore. This in turn permits faster or reduced cycling time with increased production and more judicious use of resources. In addition, a reduction in pressure needed to handle the hot lens molds, as obtained by the invention, also means the molds are exposed to less force. This means less deformation of the mold occurs. This reduction in deformation is further supplemented by the substantially rigid nature of the transfer tip, which rigidity forestalls deformation of the transfer tip itself under the forces applied.

2. Description of the Prior Art

Current manufacturing protocols for soft contact lenses call for the curing of an appropriate monomer mixture between front and back mold halves. The mold halves are typically formed by injection molding suitable plastic materials, such as polystyrene, into

a molding machine comprised of two opposing elements which interface to form the mold halves. One element has an array of regularly spaced concave recesses whereas the opposing element has a corresponding array of convex protuberances. When mated, the concave recesses and convex protuberances define therebetween a shaped volume in which the lens mold halves are produced. In operation, the opposing elements come together and molten polymer (e.g. polystyrene) is injected into the shaped volumes between the surfaces of the opposing elements. The mold halves are held for a time sufficient to set their shapes. Once sufficiently set, the opposing elements separate and the mold halves are removed.

Generally, the Back Curve (BC) mold halves provide the convex optical mold surface which shapes the portion of the contact lens that contacts the eye. The Front Curve (FC) mold halves provide the concave surface that molds the front face of the contact lens. For purposes of maintaining optimal optical integrity, the molding machine that produces the Back Curve mold sections is designed so that upon separation, the non-optically relevant, concave surfaces of the mold halves are exposed, the convex surfaces remaining within the concave recesses. While the molding machine that produces the Front Curve mold sections is nearly identical in all functional respects to the Back Curve molding machine, it operates such that when its opposing elements separate, the Front Curve optically relevant mold sections remain in contact with the convex protuberances. A single molding machine can be used to make Back Curve and Front Curve mold sections simultaneously. Molding machines and robots for which this invention are useful are disclosed in Lust et al, "Mold and Molding System for Making Ophthalmic Devices", Serial No. 09/305,886 filed May 5, 1999; Parnell et al, "In-lay Station with Alignment Assemblies and Transfer Tubes", Serial No. 09/925,403 filed August 9, 2001; and US Patent 5,545,366, all of which are incorporated herein by reference.

In production lines, removal of the mold halves, be they Front or Back Curves, is ordinarily accomplished through the use of vacuum-assisted robots. Industrially, these robots typically employ, at the working end that contacts the mold halves, soft flexible materials, such as silicones and rubbers, in the form of variously shaped end effectors, suction cups, tips, pads and the like. By convention, soft flexible materials have been employed because, in a high speed production line, the mold halves are removed when

their shape is set, not necessarily when they are cool. Because they are still relatively hot, soft flexible materials have been used in an effort to minimize damage to the lens molds, which in their heated state are still pliant and deformable. Damage to the lens molds in this regard can adversely affect, in turn, the contact lenses ultimately cast in said molds. To further forestall damage, it is common to provide a handling means, for example, a flange, somewhere on a non-critical portion of the lens mold, thus enabling the robotic transfer tip to contact only the flange or other handling means, hence leaving the optically sensitive area of the mold, where the contact lens is formed, untouched.

FIGURE 1 illustrates a prior art practice. FIGURE 1 is a side view showing transfer tip 10, made of a soft, flexible material such as silicone rubber, which tip is cylindrical in shape and open at the pickup end, defined by annular rim 14. As seen in FIGURE 1, the annular rim 14 of tip 10 contacts the injection molded lens mold 11 (depicted in FIGURE 1 as a Back Curve) at flange 15 which is provided for this purpose. Transfer tip 10 is connected via aperture 12 to a vacuum source which, when actuated, enables pickup of mold 11. Also as seen in FIGURE 1, the interior of cylindrical tip 10 has a volume 13. This must be sufficiently evacuated by the vacuum source for pickup to occur. In a typical design of this type, transfer tip 10 can be about 18mm in diameter and about 15mm high (dimensions are approximate). The applied vacuum typically necessary to effectuate pickup of mold 11 is thus about 0.8 bar (11 psi). The volume of gas 13 thus needed to be evacuated under these circumstances is approximately 3 ml. The amount of time it takes to evacuate this volume of gas affects the cycle time of the production line; that is, the time it takes a robotic transfer device to remove a lens mold half from a first location, e.g. from its injection molding machine, transfer it to a second location, e.g. a conveyor pallet, and return to the first location to repeat the process.

Although industrial useful, improvements to known practices, as for example described for and illustrated by FIGURE 1, are desirable. Among other advances sought is a reduction in applied forces, such as vacuum or positive gas pressure, inasmuch as the mold halves are removed from the molding machine at temperatures where the plastic is still pliant. Forces applied to the part at this time can distort the lens mold, leading to deformations in radius of curvature for the optically important surface on the order of 0.04 to 0.06mm (using e.g. the soft cylindrical tip of FIGURE 1), which can render the

mold unacceptable for contact lens casting. Minimization of required forces for part pickup and/or deposit would therefore improve mold quality. Moreover, it has been found that the use of current soft, flexible materials actually abet twisting of the lens mold, which itself causes deformation.

SUMMARY OF THE INVENTION

The present invention is directed to a transfer tip and a system and process for using same that achieves a reduction in applied forces and a decrease in cycle time. In one embodiment, the invention is a transfer tip for handling an injection molded ophthalmic lens mold, said lens mold having either a concave (e.g. Back Curve) or convex shape (e.g., Front Curve) and having lens mold handling means thereon, said transfer tip comprising:

a substantially rigid body portion having a distal end and a proximal end; the distal end having an outer surface that is complementary to the concave or convex shape of the lens mold to be handled, said body portion having sealing means peripheral to said outer surface for engagement with said lens mold; and

at least one aperture extending through said body portion from said proximal end to said distal end sufficient for flow communication with a source of differential pressure.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 illustrates a prior art transfer tip.

FIGURES 2A and 2B illustrate the top and edge views of a typical Front Curve lens mold; FIGURES 2C and 2D illustrate the top and edge views of a typical Back Curve lens mold.

FIGURE 3A and 3B respectively illustrate top (distal end) and side views of a transfer tip embodiment of the present invention particularly suited to the transfer of the Back Curve of an injection molded ophthalmic lens mold.

FIGURE 4A and 4B respectively illustrate top (distal end) and side views of a transfer tip embodiment of the present invention particularly suited to the transfer of the Front Curve of an injection molded ophthalmic lens mold.

FIGURE 5A and 5B respectively illustrate top (distal) and side views of a transfer tip embodiment of the present invention suited to either Front or Back Curves.

DETAILED DESCRIPTION OF THE INVENTION

The invention pertains to the handling of injection molded ophthalmic lens molds. Ophthalmic lenses in this regard include without limitation those fabricated in such molds, for example, soft contact and intraocular lenses. The invention is especially utile in the context of soft contact lenses, also known as hydrogel lenses. These lenses are typically prepared from monomers including but not limited to: hydroxyethyl methacrylate (HEMA), vinyl pyrrolidone, glycerol methacrylate, methacrylic acid and acid esters.

While not constraining the present invention, soft lenses in this regard are typically prepared by free radical polymerization of monomer mix in lens molds fabricated as has been described hereinabove. The monomer mix may contain other additives as known in the art, e.g. crosslinking and strengthening agents. Polymerization is conventionally initiated by thermal means, or is photoinitiated using either UV or visible light. In these cases, the plastic lens molds in which polymerization occurs are effectively transparent to the photoinitiating light.

Plastics that commonly serve as materials of construction for injection molded lens molds in this regard are from the family of thermoplastics and can include without limitation: polyolefins, such as low-, medium-, and high-density polyethylene, polypropylene, and copolymers thereof; polystyrene; poly-4-methylpentene; polyacetal resins; polyacrylether; polyarylether; sulfones; Nylon 6; Nylon 66; Nylon 11; thermoplastic polyester and various fluorinated materials such as the fluorinated ethylene propylene copolymers and ethylene fluoroethylene copolymers. Polystyrene is preferred.

FIGURE 2 shows an embodiment of an injection molded ophthalmic lens mold to which the present invention has especial use, it being understood that other designs and styles of lens molds are contemplated as being within the scope of the inventive practice. FIGURES 2A and 2B depict a top and side view, respectively, of a Front Curve lens mold for a soft contact lens; similarly, FIGURES 2C and 2D depict top and side views of

a Back Curve lens mold for soft contact lens. In preferred practices, the lens molds are fabricated with handling means thereon. These can be, without limitation, surfaces or other appendages that are apart from optically important central surface, such as for example a flange extending partly or entirely around the mold. In FIGURE 2, a preferred handling means is illustrated as annular flange 21 (Front Curve) and annular flange 24 (Back Curve). Tabs 22 and 25 may optionally be provided to further facilitate handling and positioning.

As indicated previously, and in further regard to FIGURE 2, in a preferred practice, the molding machine that produces the Back Curve is designed so that upon separation of the opposing mold elements, the concave surface 23 of the Back Curve lens mold is exposed. Conversely, the molding machine for the Front Curve separates such that the convex surface 20 of the Front Curve lens mold is exposed.

The transfer tip of the present invention will now be described with reference to the preferred embodiments of same illustrated at FIGURES 3, 4 and 5. The practices so illustrated and described hereinafter are especially suitable for use with lens molds having shapes similar to those shown in FIGURE 2. It will be appreciated that the inventive transfer tip is not limited to these preferred embodiments and that variations to same are within the scope and spirit of the invention.

FIGURES 3A and 3B show top and side views, respectively, of a preferred embodiment of the transfer tip of the present invention useful in handling lens molds having a concave shape, such as for example and without limitation, the Back Curve illustrated at FIGURES 2C and 2D where, for purposes of the present discussion, the concave shape is surface 23. The transfer tip is comprised of body portion 30 having a distal end (that is, the working end, or end in contact with the lens mold part that is being handled) generally at 31 and a proximal end, generally at 32, which proximal end serves as the connection to the robotic assembly or other automated transfer device (not shown) and to the source of pressure differential such as vacuum means or positive (gas) pressure (not shown). The distal end, generally at 31, has an outer surface 33 which is complementary, in shape, to the concave shape of the lens mold part to be handled. For example, outer surface 33 is of a convex shape that is complementary to concave surface 23 of the Back Curve in FIGURE 2 so as to be as close to form-fitting to surface 23 (the

area of non-optically relevant curvature of the lens mold) as practicable without impinging on same. The body portion further has a sealing means peripheral to the outer surface. In the preferred embodiment of FIGURE 3, the sealing means is in the form of annular sealing ring 31a, which can be in the form of a flange or the like surface that is preferably integral with, but can be otherwise constituted as known in the art to body portion 30. Preferably, the sealing means on the transfer tip and the handling means on the lens mold are both in the same plane; preferably both are flat, sufficient to create and maintain a seal (by e.g. vacuum) effective to enable part pickup. For example, in the embodiments shown, annular sealing ring 31a is in the same plane as annular flange 24 on the Back Curve Figure 2.

Body portion 30, including outer surface 33, is substantially rigid. For example, it is of a constitution that will not deform, and will maintain its dimensions and geometry under the elevated temperatures present on and about the lens mold as removed from the molding machine, and under the pressures of the applied force created between the sealing means of the transfer tip and the handling means (e.g. flange) of the molded part. The substantially rigid nature of body portion 30 is preferably obtained through choice of materials of construction. Generally speaking, any material having a hardness sufficient to enable it to be machined or otherwise shaped to have the requisite geometry and dimensional tolerances, e.g. flatness and the like, to achieve a workable seal, without deformation or distortion of the transfer tip when subjected to the applied sealing pressures with the lens mold, and which also has requisite thermal strength for the temperatures involved, can be used. This includes a variety of polymeric materials, metals, ceramics, cellulosic materials and the like. In a preferred practice, the material of construction has a Shore D Hardness of about 58 to about 90; more preferably about 75 to about 90; still more preferably about 85 to about 87. Serviceable polymeric materials include, without limitation, engineering grade plastics. Self-lubricating polymeric materials can be advantageously used to avoid sticking or adhering of the hot lens mold to the transfer tip. By way of exemplification only, and without constraining the scope of possible materials, preferred polymeric materials include polyacetyls (e.g. Delrin ®, which is most preferred, having a Shore D Hardness of about 86), polystyrenes, polypropylenes, polyethylenes, polyetheretherketones (PEEK), polyamides (e.g. Nylon

®), polyimides, polyamideimides (PAI), polyfluoroethylenes (e.g. Teflon ®), polyetherimides, polyesters, polycarbonates, polyethers, polyetherimides, polysulfide polymers, polysulfones, and blends and alloys of the foregoing. Polyacetyls, such as Delrin ®, are preferred. Useable metals include, again by way of example only, aluminum, stainless steel and like elemental metals and alloys that can be machined into the appropriate geometry, dimensional tolerances and sealing flatness.

In another preferred practice, the transfer tip of the invention is machined entirely from a unitary block of material, e.g. Delrin ®, using a lathe or other suitable means known in the art.

Also as shown in FIGURE 3, the transfer tip has at least one aperture 34 extending through said body portion 30 sufficient for flow communication with a source of differential pressure. The aperture can be one or more holes or bores of sufficient size drilled through the transfer tip. In a preferred embodiment, a single aperture through the center of the transfer tip is employed. The source of differential pressure can include vacuum or positive (gas) pressure sources as known in the art. For example, vacuum is drawn through aperture at the center of the transfer tip to create differential pressure in the spatial volume between the transfer tip and the lens mold. As illustrated in FIGURE 3, the transfer tip preferably has at the proximal end 32 connection means for connection to said robotic assembly or other transfer device, such as for example a threaded portion 35 for conveniently removable connection to same. Other means of connection known in the art may also be employed.

FIGURES 4A and 4B show top and side views, respectively, of a preferred embodiment of a transfer tip of the invention useful in handling lens molds having a convex shape, such as for example and without limitation, the Front Curve illustrated at FIGURES 2A and 2B, where the convex shape is surface 20. The definitions and descriptions provided for the embodiment of FIGURE 3 aforesaid apply hereto unless otherwise indicated. FIGURE 4B shows a side view of said preferred transfer tip having substantially rigid body portion 40 having a distal (working) end generally at 41 and a proximal (connection) end generally at 42 which end is ultimately connected to the robotic assembly or other transfer device and a source of pressure differential as hereinbefore described. The distal end, generally at 41, has an outer surface 43 whose

shape is complementary to the shape of the lens mold; that is, outer surface 43 is concave whereas the shape of the lens mold, e.g. the Front Curve, is convex. Again, it is preferred if the concave outer surface 43 is as close to form-fitting the convex Front Curve surface 20 as practicable without impingement. Substantially rigid body portion 40 also has thereon a sealing means in the form of an annular sealing ring 41a, which in the embodiment of FIGURE 4 is in the form of the rim or edge 41a of the body portion 40, flat and in the same plane as e.g. flange 21 on Front Curve FIGURE 2A and 2B. Body portion 40 further has at least one aperture 44 extending therethrough from said proximal end 42 to said distal end 41 for flow communication with a source of differential pressure. As depicted, it is preferred if proximal end 42 further comprises connection means for attachment to said robotic assembly or other transfer device, such as for example threaded portion 45.

FIGURES 5A and 5B show top and side views respectively, of yet another embodiment of a transfer tip of the invention, this particular embodiment being useful for handling either Front or Back Curves. Again the definitions and descriptions provided for the embodiments of FIGURES 3 and 4 aforesaid apply hereto unless otherwise indicated. FIGURE 5B shows a side view of said transfer tip having a distal (working) end generally at 51 and a proximal end generally at 52 ultimately connected to the robotic assembly or other transfer device and source of pressure differential as hereinbefore described (connection means not shown in FIGURE 5). Substantially rigid body portion 50 has at distal end 51 a sealing means in the form of an annular sealing surface 51a, which in the embodiment of FIGURE 5 is in the form of a rim or edge 51a of said body portion. Body portion 50 furthermore has a plurality of apertures 54 extending from the proximal end 52 to said annular sealing surface 51a. In a preferred practice, the plurality of apertures, e.g. holes through said rim 51a to said proximal end 52, are equally spaced around the circumference of the annular sealing surface. In the embodiment shown in FIGURE 5A, six holes, each about 60° apart, are provided. The equidistant nature and uniformity in size of the holes in the annular sealing surface 51a results in an equalization and uniformity of forces felt by the lens mold being handled. In practice, when the transfer tip of FIGURE 5 is employed to handle a lens mold having a convex

shape (e.g. Front Curve), the convex surface of same (e.g. surface 20 of FIGURE 2) is situated in void 53, with annular sealing surface 51a engaged with flanged 21.

Alternatively, another embodiment of the invention that is not shown is to modify the embodiment shown in FIGURES 5A and 5B to add the convex and concave rigid shapes 33, and 43 of the embodiments shown in the FIGURES 3A and 3B and FIGURES 4A and 4B while maintaining the plurality of apertures 54 as shown in FIGURES 5A and 5B. The apertures 34 and 44 as shown in FIGURES 3A and 3B and FIGURES 4A and 4B are optional.

In the most preferred embodiments, the transfer tips of FIGURES 3, 4 and 5 are machined from a unitary block of polyacetyl, such as Delrin ®, having a Shore D Hardness of about 86. In the practice of the invention using the most preferred embodiments of FIGURES 3 and 4, radial distortions of the lens molds being so handled of about 0.01 to 0.02mm were observed. Without being bound to any theory, it is believed said reductions were due partly because less evacuation time and less vacuum was required, and partly to the fact that the lens molds could be removed from the injection molding machines at a hotter temperature using the transfer tip of the invention as opposed to prior art tips.